PIBS 1576

Industrial Waste Diversion Program

Final Report #13

AMMONIA RECOVERY FEASIBILITY STUDY

JUNE 1991

Ontario
Environment
Environnement

ISBN 0-7729-7543-4

INDUSTRIAL WASTE DIVERSION PROGRAM

FINAL REPORTS # 13

AMMONIA RECOVERY FEASIBILITY STUDY

Report Prepared For:

Waste Management Branch
Ontario Ministry of the Environment

First Printed June 1991
Reprinted March 1992

PRINTED ON
RECYCLED PAPER
IMPRIMÉ SUR
DU PAPIER RECYCLÉ

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AMMONIA RECOVERY FEASIBILITY STUDY

Report Prepared For:

Waste Management Branch
Ontario Ministry of the Environment

In Consultation With:

Kilborn Limited

DISCLAIMER

This report is in partial fulfillment of conditions of a grant given to Algoma Byproducts Corp. by the Ministry of the Environment under the Industrial Waste Diversion Program. The report was prepared by Kilborn Limited for Algoma Byproducts Corp. and documents results of work for which the Ministry of the Environment provided financial assistance.

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Kilborn has followed standard procedures in preparing the evaluation in the report, but the Report is based in part on details, information and assumptions provided by others and Kilborn, therefore, cannot guarantee the correctness of the Report; but to the extent of its investigation and within the scope of the work delegated to it Kilborn believes that the Report is substantially correct.

1.0 SUMMARY

A preliminary feasibility study was prepared to evaluate the production of Ammonium Sulphate from a waste ammonia stream produced by Algoma Steel. Two operations were evaluated:

- production of 6,100 tonnes per year of Ammonium Sulphate from a 5 Wt. percent ammonia solution (31,500 tonnes per year)
- production of 12,200 tonnes per year Ammonium Sulphate from a 10 Wt. percent ammonia solution (31,500 tonnes per year)

The ammonia solution is converted to ammonium sulphate by reaction with 93 Wt. percent Sulphuric Acid in a vacuum crystallizer. Water is vaporized to crystallize the ammonium sulphate. The product is recovered by centrifuge and dried in a fluid bed dryer. The ammonium sulphate is produced as a crystalline product.

Technical information for the two operations is presented in Table 1.1.

The facility is designed to process 5 and 10 Wt. percent ammonia solutions in order to cover the anticipated variation in ammonia content of the feed solution. The estimated capital cost of the facility to recover ammonia as ammonium sulphate is $2.1 million Canadian. The estimate is based on fourth quarter 1989 dollars and includes process unit, offsite facility and utility system direct costs, home office engineering and construction management indirect costs, and project contingency.

The estimated annual operating cost for the ammonia recovery facility is $1.3 - 1.6 million for the 5 and 10 Wt. percent ammonia solutions, respectively. The major difference in the operating cost figures is the cost of sulphuric acid required to convert the ammonia to ammonium

sulphate. On a unit of production cost basis, the operating cost is $130.85 - 213.90 per tonne of ammonium sulphate for the 10 and 5 Wt. percent ammonia solutions, respectively. The estimate includes the cost of sulphuric acid at $60.00 per tonne, operating and maintenance labour costs, maintenance parts, utilities, local taxes and insurance.

If Algoma Byproducts Corp. proceeds with the ammonia recovery project, meetings should be held with Algoma Steel to determine ways to maximize ammonia concentration in the waste stream, to establish the cost of utilities provided to the recovery plant and to explore sharing of operating, maintenance and overhead staff duties.

TABLE 1.1
TECHNICAL SUMMARY
AMMONIUM SULPHATE PROCESS

	5 Wt.% - 6100 tpy Plant Operation	10 Wt.% - 12200 tpy Plant Operation
FEEDSTOCKS		
Ammonia Solution, tonnes/yr	31500	31500
93 Wt.% Sulphuric Acid, tonnes/yr	4880	9750
PRODUCT		
Ammonium Sulphate crystals, tonnes/yr	6110	12220

2.0 INTRODUCTION

Kilborn Limited was requested by Algoma Byproducts Corp. to assess the technical feasibility and capital cost of recovering ammonia as ammonium sulphate from a waste ammonia stream produced by Algoma Steel at Sault Ste. Marie, Ontario. The study was based on an analysis of the ammonia solution provided by ORTECH International.

Ammonia from the Algoma Steel waste ammonia solution is recovered as ammonium sulphate by reaction with sulphuric acid in a crystal suspension tank. Water is removed in the vaporizer, centrifuge and dryer. The ammonium sulphate is recovered for sale as a crystalline product.

The plant investigated in the study was designed to process 90 tonnes/day of waste ammonia solution, which varies in ammonia concentration from 5 to 10 Wt. percent. Two operations were studied in order to cover this expected variation in ammonia content:

- Recovery of ammonia from a waste ammonia stream containing 5 Wt. percent ammonia, resulting in the production of 6,110 tonnes per year of ammonium sulphate. The crystallizer was designed for this operation, consistent with maximum water vapor removal.

- Recovery of ammonia from a waste ammonia stream containing 10 Wt. percent ammonia, resulting in the production of 12,220 tonnes per year of ammonium sulphate. The plant, except the crystallizer, was designed for this operation to provide for processing maximum amounts of both feedstocks and products.

Preliminary process designs were completed for the plant configurations based on information provided by Algoma Byproducts Corp., information received from equipment vendors and in-house data. Capital and operating cost estimates were developed from the process design information.

3.0 TECHNICAL ASSESSMENT

3.1 PROCESS DESCRIPTION

Ammonia is converted to ammonium sulphate as illustrated by the following reaction:

$$2NH_3 + H_2SO_4 \text{-------}> (NH_4)_2SO_4$$

The ammonium sulphate is recovered as a crystalline product.

3.2 PRELIMINARY PROCESS DESIGN

A preliminary process design was completed for the processing of 90 tonnes per day of waste ammonia solution. A Simplified Flow Diagram for the facilities is shown as Figure 3.1. Two operations, for 5 and 10 Wt. percent ammonia solutions, were evaluated as follows:

- with 5 Wt. percent ammonia, the plant is capable of producing 6,110 tonnes per year of ammonium sulphate. A total of 4,880 tonnes per year of 93 Wt. percent sulphuric acid is required and 3,510 Kg/Hr of water vapor is removed via the vaporizer.

- with 10 Wt. percent ammonia, the plant is capable of producing 12,220 tonnes per year of ammonium sulphate. A total of 9,750 tonnes per year of 93 Wt. percent sulphuric acid is required and 3,280 Kg/Hr of water vapor is removed via the vaporizer.

In both operations, 93 Wt. percent sulphuric acid is received at the plant by bulk truck, unloaded and transferred into a storage tank. Waste ammonia solution, with 5 to 10 Wt. percent ammonia, from Algoma Steel is temporarily stored in a solution tank.

Both feedstocks, sulphuric acid and waste ammonia solution, are fed to a crystallizer/vaporizer system for conversion of the ammonia to ammonium sulphate. Water is evaporated to crystallize the ammonium sulphate.

Ammonium sulphate crystals are recovered from the crystallizer net slurry stream by a centrifuge and are dried in a fluid bed dryer, before being routed to storage.

Mother liquor from the centrifuge, saturated with ammonium sulphate, is recycled to the crystallizer.

3.3 MATERIAL BALANCES

Overall material balances are presented in Tables 3.1 and 3.2 for the two operations:

- Processing a 5 Wt. percent ammonia solution from Algoma Steel to produce 6,110 tonnes per year of ammonium sulphate crystalline product.

- Processing 10 Wt. percent ammonia solution from Algoma Steel to produce 12,220 tonnes per year of ammonium sulphate crystalline product.

A 24 hour per day, 350 day per year operation has been assumed.

The material balances were developed on the basis of information supplied by Algoma Byproducts Corp.

3.4 UTILITY REQUIREMENTS

The ammonia recovery facility will be located on, or adjacent to, Algoma Steel property in order to minimize transportation costs for the waste ammonia stream which contains 90-95 Wt. percent water. In this context, it has been assumed that all utilities required to support the ammonia recovery operation (steam, cooling water, electricity, firewater) will be supplied by Algoma Steel.

Overall utility requirements were estimated for both operations. Following is a summary of the estimated utility requirements, based on the maximum consumptions of each operation:

LP Steam

Vaporizer/Crystallizer Peak Rate (5 Wt.% Ammonia Operation)	3500 Kg/Hr
Dryer Peak Rate (10 Wt.% Ammonia Operation)	300 Kg/Hr
Average LP Steam Consumption	3600 Kg/Hr

Cooling Water

Vaporizer/Crystallizer/Condenser	140 M^3/Hr

Electricity

Electricity	50 KWH

FIGURE 3.1

PROCESS TO CONVERT AQUA AMMONIA TO AMMONIUM SULPHATE

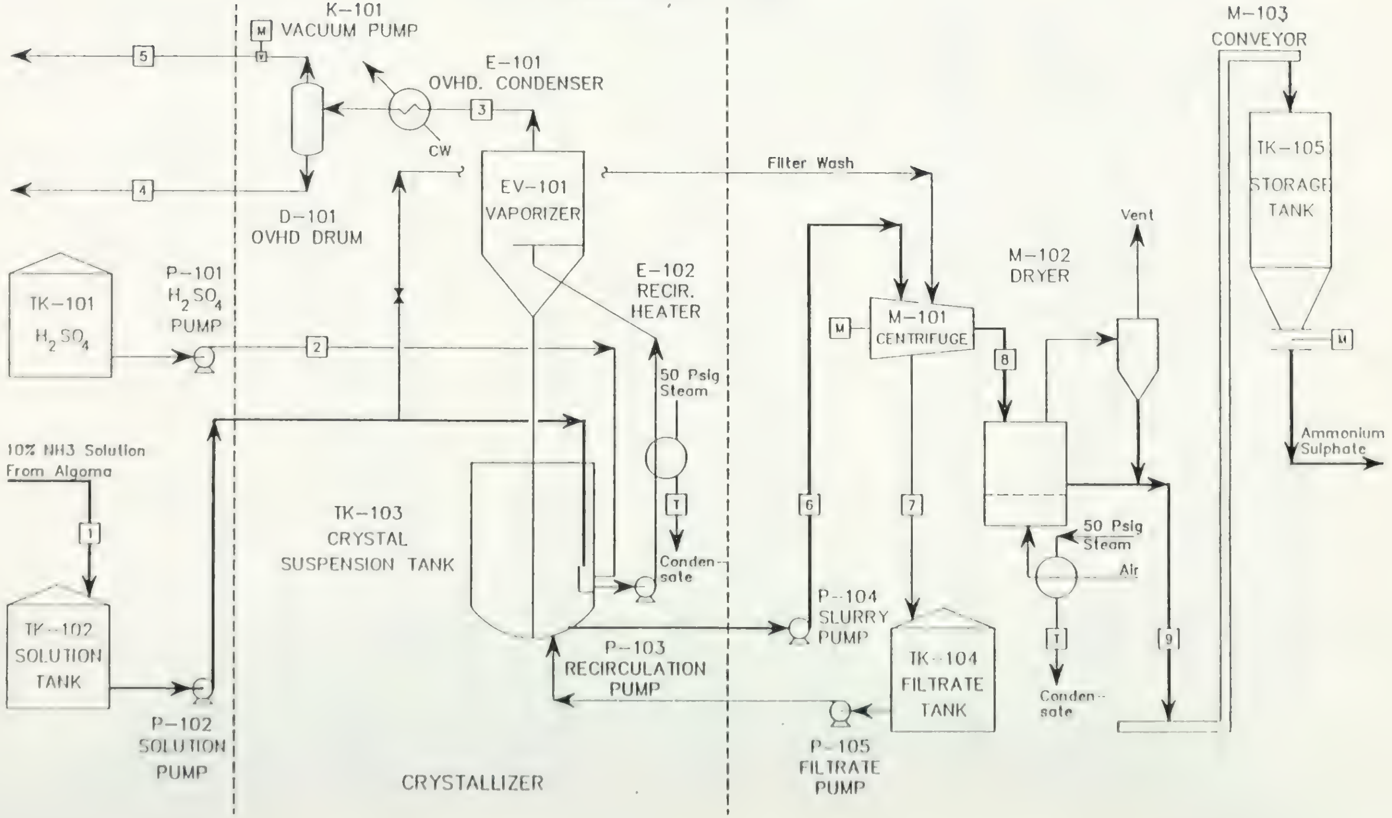

Table 3.1
Material Balance
Case 1
(5 Wt% Waste NH_3 Stream)

Stream No.		1	2	3	4	5	6	7	8	9
Stream Name		NH_3 Soln Fm Algoma	H_2SO_4	Vapor To Vac.Pump	Condens. Fm Vac.Pump	Vent Gas Fm Vac.Pump	Soln To Slur.Tk	Filtrate To Soln Tk	Soln To Dryer	$(NH_4)_2SO_4$ Product
Deg.C		25	25	61	52	52	61	61	61	---
KPa		101.3	101.3	20.7	13.8	13.8	20.7	101.3	101.3	101.3
Component: Kg/Hr										
NH_3		187.5								
H_2SO_4			540.0							
$(NH_4)_2SO_4$							1340.5	613.0	727.5	727.5
Water		3562.5	40.6				839.2	749.2	89.9	
Vapour				3513.2						
Vent Gases						54.9				
Condensate					3458.2					
Total Wt.										
	Kg/Hr	3750	581	3513	3458	55	2180	1362	817	728
	T/Yr	31500	4877	---	---	---	---	---	---	6111
	Lb/Hr	8267	1280	7745	7624	121	4805	3003	1802	1604
Chem.Only	Tonne/D	4.5	13.0	---	---	---	32.2	14.7	17.5	17.5
	Wt %	5	93	---	---	---	62	45	89	100
Solid	Wt %	---	---	---	---	---	30	---	80	--
Sp.Gr.		1.000	1.823	---	1.000	---	1.072	1.238	---	0.817 (Bulk)
Total Vol	USGPM	17	1	---	15	---	9	5	---	---
	M3/Hr	3.8	0.3	---	3.5	---	2.0	1.1	---	---
	ACFM	---	---	15413	---	352	---	---	---	---
	AM3/M	---	---	436	---	10	---	---	---	---
Deg.F		77	77	142	126	126	142	142	142	---
PSIA		14.7	14.7	3	2	2	3	14.7	14.7	14.7

Table 3.2
Material Balance
Case 2
(10 Wt% Waste NH3 Stream)

Stream No.		1	2	3	4	5	6	7	8	9
Stream Name		NH3 Soln Fm Algoma	H2SO4	Vapor To Vac.Pump	Condens. Fm Vac.Pump	Vent Gas Fm Vac.Pump	Soln To Slur.Tk	Filtrate To Soln Tk	Soln To Dryer	(NH4)2SO4 Product
Deg.C		25	25	61	52	52	61	61	61	---
KPa		101.3	101.3	20.7	13.8	13.8	20.7	101.3	101.3	101.3
Component: Kg/Hr										
NH3		375.0								
H2SO4			1079.9							
(NH4)2SO4							2680.8	1225.9	1454.9	1454.9
Water		3375.0	81.3				1678.2	1498.3	179.8	
Vapour				3276.4						
Vent Gases						51.2				
Condensate					3225.1					
Total Wt.	Kg/Hr	3750	1161	3276	3225	51	4359	2724	1635	1455
	T/Yr	31500	9754	---	---	---	---	---	---	12221
	Lb/Hr	8267	2560	7223	7110	113	9610	6006	3604	3207
Chem.Only	Tonne/D	9	25.9	---	---	---	64.3	29.4	34.9	34.9
	Wt %	10	93	---	---	---	62	45	89	100
Solid	Wt %	---	---	---	---	---	30	---	80	---
Sp.Gr.		1.000	1.823	---	1.000	---	1.072	1.238	---	0.817 (Bulk)
Total Vol	USGPM	17	3	---	14	---	18	10	---	---
	M3/Hr	3.8	0.6	---	3.2	---	4.1	2.2	---	---
	ACFM	---	---	14374	---	328	---	---	---	---
	AM3/M	---	---	407	---	9	---	---	---	---
Deg.F		77	77	142	126	126	142	142	142	---
PSIA		14.7	14.7	3	2	2	3	14.7	14.7	14.7

4.0 FINANCIAL

4.1 CAPITAL COST ESTIMATE

A capital cost estimate was developed for the plant capable of processing between 5 and 10 Wt. percent ammonia in the waste ammonia stream.

The capital cost estimate, in fourth quarter 1989 dollars, is summarized below:

Direct Costs,	$1,502,000
Indirect Costs,	$ 568,000
TOTAL PROJECT COST,	$2,070,000

All process unit and support facility direct costs were developed from budget prices for individual pieces of equipment or package units plus typical percentages for freight (to deliver equipment to the site), installation of the equipment, process piping, instrumentation, electrical, structural and civil work. These percentages are based on historical data compiled from past similar jobs.

Indirect costs include home office engineering and construction management costs at 15 percent of total direct costs and project contingency at 20 percent of total direct plus home office costs.

As discussed in Section 3.4 of this report, it has been assumed that the plant will be located on, or adjacent to, Algoma Steel property. This will permit the use of their existing major utility systems, in particular, steam, cooling water, electrical and firewater systems.

Details of the capital and equipment cost estimates are provided in Table 4.1.

TABLE 4.1

KILBORN

GENERAL ESTIMATE SUMMARY

Client: ALGOMA BYPRODUCTS CORP.
Project Title: AQUA AMMONIA CONVERSION
Project No.: 5191-15

Estimate Type: PRELIMINARY (CLASS 4)
Estimate No. 1

Currency: $ Cdn.
Estimate Valid For: Yr. 89 4th Quart.

Total Direct Cost		1,502,000
Indirect Costs		
Home Office Engineering & Construction Management (15%)	225,000	
Contingency (20%)	343,000	
Total Indirect Cost		568,000
TOTAL PROJECT COST:		2,070,000

KILBORN

Project Engineer: ____________ Date: ____________

Project Manager: N E Anderson Date: 18 Dec 1989

Vice President: ____________ Date: 20 Dec 1989

TABLE 4.1

PROCESS EQUIPMENT

ESTIMATE SUMMARY CASE 3

Client: ALGOMA BYPRODUCTS CORP. DATE: 13-Dec-89
Estimate Type: PRELIMINARY (CLASS 4)
Project Title: AQUA AMMONIA CONVERSION

EQUIPMENT		DELIVERED COST	
Mechanical Equipment		$ 319,000	
Pumps		$ 13,500	
Tanks		$ 68,500	
Package Units (Incl. Inst. Cost)		$ 470,000	
PROCESS EQUIPMENT			$ 871,000
INST. COST	12.50 % of P Equip (Less Package Units)		$ 50,000
INSTALLED COST			$ 921,000
Piping	25.00 % of PEIC	$ 230,000	
Instrumen.	10.00 % of PEIC	$ 92,000	
Electrical	10.00 % of PEIC	$ 92,000	
Structural	5.00 % of PEIC	$ 46,000	
Civil	5.00 % of PEIC	$ 46,000	
Building (40 ft x 60 ft)	Allowance	$ 75,000	
SUBTOTAL			$ 581,000
DIRECT COST PROCESS EQUIPMENT			$ 1,502,000

TABLE 4.1

KILBORN

EQUIPMENT PRICE ESTIMATE

Client: ALGOMA BYPRODUCTS CORP.
Project Title: AQUA AMMONIA CONVERSION
Equipment Type: PACKAGE UNIT

Project No. 5191-15
Date: Nov. 1989 Rev.No. A
Issue Date: Nov. 1989

Equipment No. Item No.	Quantity	Description	Material	1989 Can $
EV-101/TK-103	1	EVAPORIZER/CRYSTALLIZER C/W Overhead Drum (D-101), Condenser (E-101), Vacuum Pump (K-101); Recycle Heater (E-102) & Pump (P-103)	316 SS	470,000
		SUBTOTAL		470,000

PRICES INCLUDE 5% FREIGHT +
5% EXTRAS ALLOWANCE,
FST & PST EXEMPT

TABLE 4.1

KILBORN

EQUIPMENT PRICE ESTIMATE

Client: ALGOMA BYPRODUCTS CORP.
Project Title: AQUA AMMONIA CONVERSION
Equipment Type: MECHANICAL

Project No. 5191-15
Date: Nov. 1989 Rev.No. A
Issue Date: Nov. 1989

Equipment No. Item No.	Quantity	Description	Material	1989 Can $
M-101	1	(NH4)2SO4 CRYSTAL CENTRI.	304 SS	121,000
M-102	1	(NH4)2SO4 CRYSTAL DRYER	304 SS	176,000
M-103	1	(NH4)2SO4 CRYST.CONVEYOR	PLASTIC/CS	22,000
		SUBTOTAL		319,000

PRICES INCLUDE 5% FREIGHT +
5% EXTRAS ALLOWANCE.
FST & PST EXEMPT

TABLE 4.1

KILBORN

EQUIPMENT PRICE ESTIMATE

Client:	ALGOMA BYPRODUCTS CORP.	Project No. 5191-15	
Project Title:	AQUA AMMONIA CONVERSION	Date: Nov. 1989	Rev.No. A
Equipment Type:	PUMPS	Issue Date: Nov. 1989	

Equipment No. Item No.	Quantity	Description	Material	1989 Can $
P-101	1	93 % SULPHURIC ACID PUMP	DCI	2,600
P-102	1	NH3 SOLUTION PUMP	DCI	2,400
P-104	1	(NH4)2SO4 SLURRY PUMP	316 SS	4,400
P-105	1	FILTRATE PUMP	316 SS	4,100
		SUBTOTAL		13,500

PRICES INCLUDE 5% FREIGHT +
5% EXTRAS ALLOWANCE,
FST & PST EXEMPT

TABLE 4.1

KILBORN

EQUIPMENT PRICE ESTIMATE

Client: ALGOMA BYPRODUCTS CORP.
Project Title: AQUA AMMONIA CONVERSION
Equipment Type: TANKS

Project No. 5191-15
Date: Nov. 1989 Rev.No. A
Issue Date: Nov. 1989

Equipment No. Item No.	Quantity	Description	Material	1989 Can $
TK-101	1	93 % SULPHURIC ACID TANK	CS	22,000
TK-102	1	NH_3 SOLUTION TANK	CS	11,000
TK-104	1	FILTRATE TANK	CS	4,500
TK-105	1	$(NH_4)_2SO_4$ STORAGE TANK	CS	31,000
		SUBTOTAL		68,500

PRICES INCLUDE 5% FREIGHT +
5% EXTRAS ALLOWANCE.
FST & PST EXEMPT

4.2 ANNUAL OPERATING COST

Annual operating cost estimates were developed for the two ammonium sulphate operations. It is assumed that the operating cost is the same for both operations, except for the cost of feedstocks. These annual operating costs, presented in Table 4.2 and 4.3, include the costs for feedstocks, operating and maintenance labour, maintenance parts, utilities, local taxes and insurance. A summary of the total annual operating costs, in 1989 dollars, follows:

	5 Wt. % - 6100 tpy Plant Operation	10 Wt.% - 12200 tpy Plant Operation
Feedstock Costs, $/Yr	293,000	585,000
Labour Costs, $/Yr	448,000	448,000
Other Costs, $/Yr	566,000	566,000
TOTAL OPERATING COST, $/Yr	1,307,000	1,599,000

The prices of raw materials, Sault Ste. Marie location, were established as follows:

93 Wt.% Sulphuric Acid	$60.00 per tonne
5 Wt.% Ammonia Solution	N/C
10 Wt.% Ammonia Solution	N/C

It is assumed that the ammonia solution will be delivered to the Algoma Byproducts plant free of charge as it is a waste stream that is currently being incinerated.

Plant labour and overhead costs are based on estimated operations, maintenance and plant overhead staffs, as follows:

	5 -10 Wt.% Both Operations
Operations Staff	5
Supervisors	1
Maintenance Staff	1
Overhead Staff	1
TOTAL PLANT STAFF	8

As discussed in Section 3.3 of this Report, a 24 hour per day, 350 day per day operation has been assumed for the plant. The estimated operating and maintenance staff requirements are based on this operating philosophy, and are assumed to be the same for both operations. Since it has been assumed that the plant will be located on, or adjacent to, Algoma Steel property, some of the supervision, maintenance and overhead staff responsibilities may be shared, on a contract basis, by existing personnel at Algoma Steel.

Average annual salaries, including all fringe benefits, were set at $40,000. The cost of office supplies and miscellaneous services was estimated to be 40 percent of labour and overhead staff costs.

The annual cost of maintenance parts is estimated at 2 percent of the fixed capital cost. Annual local taxes and insurance were each estimated at one-half of one percent of fixed capital investment.

The following costs were used for utilities required for the ammonium sulphate facility, on the assumption that they would be supplied across the fence by Algoma Steel.

Electricity	$ 0.05/KWH
LP Steam	$ 15.00/tonne
Cooling Water	$ 0.025/M3

TABLE 4.2
ANNUAL FEEDSTOCK COST ESTIMATES, $K/YR

	5 Wt.% - 6100 tpy Plant Operation	10 Wt.% - 12200 tpy Plant Operation
93 Wt.% Sulphuric Acid		
tonnes/yr	4880	9750
$/tonne	60	60
$K/Yr	293	585
Ammonia Solution		
tonnes/yr	31500	31500
$/tonne	N/C	N/C
$K/Yr	N/C	N/C
TOTAL FEEDSTOCK COST, $K/Yr	293	585

TABLE 4.3
ANNUAL OPERATING COST ESTIMATES, $K/YR

	5 Wt.% - 6100 tpy Plant Operation	10 Wt.% - 12200 tpy Plant Operation
Feedstocks Costs	293	585
Labour and Overhead Costs	448	448
Maintenance Parts	41	41
Local Taxes	10	10
Insurance	10	10
Utilities		
- Electricity	21	21
- Steam	454	454
- Cooling Water	29	29
TOTAL OPERATING COST, $K/Yr	1307	1599

5.0 CONCLUSIONS & RECOMMENDATIONS

Based on an overall assessment of the facilities required to recover ammonia as ammonium sulphate from a waste ammonia stream, a number of technical and financial conclusions can be drawn:

1. Recovery of ammonia as ammonium sulphate is a technically viable, commercially proven process. The ammonium sulphate is recovered as a crystalline product for sale as a high nitrogen content fertilizer.
2. The production rate of ammonium sulphate is 6,100 - 12,200 tonnes per year, depending on the quantity of ammonia in the waste stream.
3. The unit operating cost for the facility is $130.85 - 213.90/tonne of ammonium sulphate produced. This cost is highly dependent on the concentration of ammonia in the waste stream as the production rate is proportional to the quantity of ammonia in the waste stream.
4. Construction and operation of the ammonia recovery facility is environmentally attractive as the waste ammonia stream is currently being incinerated.

If Algoma Byproducts Corp. proceeds with the ammonia recovery project, the following key steps should be implemented.

1. Discussions with Algoma Steel to determine if operating procedures can be introduced to maximize ammonia concentration in the waste stream, in order to minimize steam consumption in the recovery facility.
2. Meetings with Algoma Steel to determine the cost of utilities provided to the ammonia recovery facility and to explore the possibility of sharing operating, maintenance and overhead staff duties, in order to minimize labour costs for the recovery facility.